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16. Abstract Earth-based, fully automatic "robotic" telescopes have been in routine operation for a number of years. As their number grows and their distribution becomes global, increasing attention is being given to forming networks of various sorts that will allow them, as a group, to make observations 24 hours a day in both hemispheres. We have suggested that telescopes based in space be part of this network. We further suggested that any telescope on this network be capable of asking, almost in real time, that other robotic telescopes perform support observations for them. When a target of opportunity required support observations, the system would determine which telescope(s) in the network would be most appropriate to make the observations and formulate a request to do so. Because the network would be comprised of telescopes located in widely distributed regions, this system would guarantee continuity of observations. This report summarizes our efforts under this contract. We proposed to develop a set of data collection and display tools to aid simultaneous observation of astronomical targets from a number of observing sites. We planned to demonstrate the usefulness of this toolset for simultaneous multi-site observation of astronomical targets. Possible candidates for the proposed demonstration included the Extreme Ultraviolet Explorer (EUVE), International Ultraviolet Explorer (IUE), and ALEXIS, sounding rocket experiments. Ground-based observatories operated by the University of California, Berkeley, the Jet Propulsion Laboratory, and Fairborn Observatory in Mesa, Arizona were to be used to demonstrate the proposed concept. Although the demonstration was to have involved astronomical investigations, the tools were to have been applicable to a large number of scientific disciplines. The software tools and systems developed as a result of the work were to have been made available to the scientific community.			
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**AstroNet: a Tool Set for Simultaneous, Multi-Site Observations  
of Astronomical Objects: Final Report**

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This document is the final report on the development of a tool-set for simultaneous, multi-site observations of astronomical objects. This will be our last status report for this project. What follows is a summary of the Tool Set project to date.

Due to severe funding cutbacks and denial of two requests for computing hardware, we are unable to complete our original goals. However, significant a portion of the goals have been achieved and could be demonstrated if such hardware were made available. Interim progress has been documented in the Boulder Summer Workshop reports as well as periodic progress reports.

After the implementation of our specific needs into the ATIS based programs developed by AutoScope, the user interface aspect of the project, which runs on a PC or Sun Workstation with a window environment, was designed. A person would then be able to link into a telescope, via internet, and remotely control the telescope and observe the experiment on his/her own computer in real-time. Extensive testing of the software described below has been performed. Initially, testing was done by linking into a Berkeley based PC, which ran a control program attached to a telescope simulation program provided by AutoScope. Because the testing was carried out in Boston, and the software was located in Berkeley, and required 3 PC's to run, testing needed to be coordinated between the Berkeley and Boston groups. To make testing more convenient, a comparable telescope simulator program that could be sent over internet and run on a Sun Workstation in Boston, was written.

Three telescope control programs have been written and tested. In addition to the test of the

autorun.c (the telescope supervisor program) in Berkeley, using a modem link between user and a simulated telescope, a successful test using autorun.c via internet has been completed using a simulated telescope, located in Berkeley, and a Sun Workstation in Boston. This was done for a group of objects using a computer script as well as for real-time/interactive tests. Control.c (the multi-telescope control program) has also been tested.

Each observer/telescope link provides a graphical user interface panel which displays the telescope information, parameter values, and a scrollbar in the window where text messages are displayed. To make real time commands to the telescope selected or to enter telescope parameters, the user can either type directly into the telescope graphical user window on the appropriate variable line, or s/he can type a command to set the value for a specified parameter in the user's control window which is sent to the 'autorun' process for the currently selected telescope. The user can also write a procedure written in the Tool Command Language (tcl) to set values for "batch mode" observing in either real-time or at a later time. We have also tested the "robustness" of the system by connecting to and disconnecting from various simulated telescope sites during the multi-site tests. We have conducted several tests of autowatch.c, which monitors the progress of an observation in real-time. A user can have several 'autowatch' processes running on his/her workstation, simultaneously, each monitoring a different telescope. The graphical user interface panel used in 'autowatch' is the same as the one seen by the 'active' user in 'autorun', except that all controls in the 'autowatch' panel are disabled, except for the scrollbar in the window where text messages are displayed. Tests of this procedure included using autowatch.c on a single site, as well as during a multi-site session of autorun.c. We were also able to start and end an autowatch session while running autorun without disturbing any other processes running. Multiple autowatch sessions are also now possible.

All data are displayed in the graphical user display, and the "active" user has the option of having the data written to a FITS formatted file, which is then automatically sent to the user's

current directory. This option has also been tested.

All necessary software has been put on internet and received by other users using ftp. Programs have also been made available to set up simulated telescope sites (for testing) at locations other than Berkeley. This software was designed to be freely distributed and to run with a minimum of system administration. We have also tested the networking, user, and software capabilities using a simulated telescope program. All aspects of this system, including all software documentation, are detailed in a Software Working Document.

All original parameters are working properly, and several others have been added. Our project has been able to use successful aspects of other projects, in which members of our group have been involved, and add them to the existing interface and networking capabilities. All data is now taken and sent to the user in the standard FITS format, and the capability to access photometric data from the user interface is available. We have completed updating and revising the “autorun”, “autosrv”, and “autoscope” programs, so that anyone connected to the Internet can operate an Autoscope telescope, provided they are near a telephone line. The network and user end now have all basic capabilities.

We have also added several items to make the ToolSet easier to use, such as included online Help facilities, menus, and making sure that all software and other computing facilities needed are in the Public Domain. We have upgraded the “autorun” program to work with the new release of TCL, which includes the capability to make plots (using the BLT extension of TCL), making data analysis much easier, as well as making the graphics more dynamic and improving interactive abilities.

We have also pursued the educational aspect of this project. We have written to a few astronomers that work at small colleges to see what kind of interest would exist for our project. This would be an important part for the networking and “completeness” goals in our project. These small colleges would receive all of our networking software by ftp and install it into their telescope systems.

While their telescopes may or may not be automated, those observing would still be able to receive observation requests and information over the internet, and collaborate or assist other astronomers, as well as watch what they were observing. This would benefit both the astronomers sending out requests, as their data set could then be complete and more self-contained, and the student by giving them a first look at “real” astronomy. We have also begun to get in contact with amateur astronomers over an electronic bulletin board to see what interest might exist in that area, what sort of equipment the typical amateur astronomer has (especially computer related) and what use this program could be to them.

Interest in this program has been shown by responses to an electronic bulletin board notice summarizing the work being done and asking for feedback from the professional and amateur astronomical community. Potential network members include amateur astronomers that mainly want to be able to watch astronomy being done, other amateurs that have fully computerized telescopes that wish to be full participants in the network, professional astronomers at small colleges and universities who see this project as a way to enhance their research potential and broaden their students’ education, and professional astronomers who would like to use this network to further their own research by gaining support observations and complete data sets. Other telescope groups have also expressed an interest in AstroNet, such as the North American Small Telescope Cooperative, headed by Dr. Jason Cardelli of the University of Wisconsin. Also interested are email groups concentrating on sharing knowledge about robotic telescope and interfaces, such as the “Robotic Telescope Interface”, an electronic bulletin board whose home base is Bradford University, UK. Other international interest has come from the Czech Republic, British Columbia, Holland, and New Zealand.

We are working to incorporate the work of the NASA Ames AI group. We have had meetings with Mark Drummond and others at NASA Ames and have used their current software to form our own scheduling routine. Similar to our own software, their scheduling code utilizes TCL and

tk. Also, their telescope interface is written in ATIS. However, they are currently rewriting their software into C from LISP, and expect to be done by the beginning of next year.

We have spent considerable time improving the user interface and data display of the "autorun" program. An example of an updated, simulated autorun session is shown in Figure 1. The objects being observed are Cygnus A and B, a binary star system. The Graphical User Interface window is located in the right portion of the figure, titled 'autorun'. In it, the various commands, such as 'Move', 'Acquire', 'Capabilities', 'Weather', etc. are activated by clicking on the appropriate button. Parameters can also be inputted by clicking on the appropriate line and typing directly into the window. The middle, scrollbarred section of the window is where commands and messages are displayed for the user. All of these things have been previously presented and described in past status reports.

New features include the image display window, SAOImage, seen in the middle of the screen in Figure 1. SAOImage, developed by the Smithsonian Astrophysical Observatory, is used throughout astronomy and space physics, and all data analysis that are available through SAOImage are available. These include options such as aperture photometry, image arithmetic, and image calibration. Below the SAOImage window is the User Command window, in which 'autorun' is originally called, is an alternate place to call commands and set parameters, as described in previous reports. The upper left portion of the figure is the graphic display of photometric data, again of Cygnus A and B, which is updated as more data are taken and plotted against time (Julian Date). This would be especially useful for variable objects, such as binary stars and pulsars. All data are stored in FITS format. Security and data compression issues are still being addressed.

A full demonstration and presentation of the AstroNet project were reported at the 1994 AISRP Workshop III Conference in Boulder, CO on July 15, 1994. We have also prepared and submitted an article for the Scientific Information Systems Newsletter, describing our work and presenting

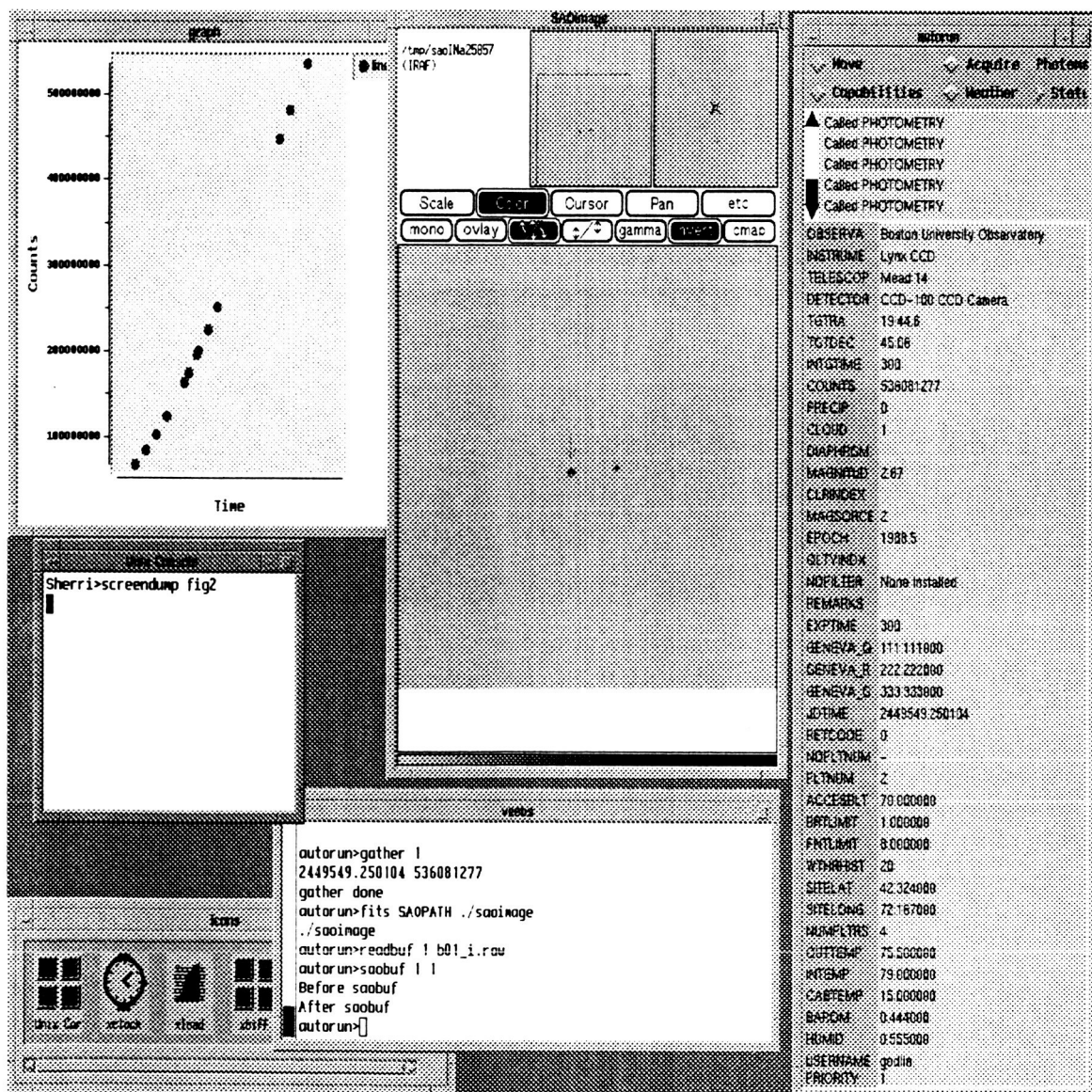


Figure 1: Simulated Aurorun Session Display

examples of our system to the community.

We have documented our own software to make it easier to use. We have also organized the software to make it easier to expand and extend to other platforms. We have removed certain aspects of the code which are essentially a client/server mode. By doing this, we can add other tools and different types of telescopes. However, this work is incomplete due to funding stoppage and denial of computer procurement for software testing. We have also begun working with the new version of the telescope command language, ATIS94, which is much more versatile and comprehensive than the older version, which could not incorporate any instruments other than photometers.

We have attempted to plan a real- telescope test, as well as a real-time multi-site test. Unfortunately, the funding we requested to buy computers and continue this work for this test was denied. This project needs computer support to test and develop the interfaces and multi-site possibilities, and without it, it is not possible to continue. Also, any hardware testing that needs to be done would require additional equipment and time, both of which are no longer funded.

Before finalizing the project, we plan to have all of our software documented and tested, as well as a finished software document describing how Tool-Set work and how to it is used. However, given the incompleteness of the software, we see little value in completing the software documentation. The software includes the telescope/user/internet interface, photometry links and on-line help. We also would like to have a rigorous scheduling/planning routine, but may not be able to include it in its present form.